Nonmotorized Urban Transportation for Emerging Cities in India

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Urban transportation is a serious problem faced by the cities of developing countries such as India. Large metropolitan cities with more than 1 million in population are recording a rapid increase in population, urban area, and automobile ownership. The phenomenal growth has created intense congestion, because costs prohibit the provision of adequate transportation facilities. The costs of providing roads and other transportation infrastructure increase greatly with the increase in city size. In a recent census, the rate of rural urban migration to cities with populations between 300,000 and 1 million and emerging cities with populations between 100,000 and 300,000 has been observed to be higher than the rate of rural urban migration to major metropolitan cities. At present, these emerging cities have few transportation problems, and with proper land use transportation planning, a sustainable urban form can be provided. A nonmotorized transportation system for the sustainable urban form for emerging cities is described. It compares the savings in fuel, air pollution, and modal splits for different city sizes in India with cities in the United States. Specific infrastructure improvements are suggested to support nonmotorized transportation. Finally, a framework for sustainable urban form is introduced, and the planning requirements are described.

Urban transportation is one of the biggest problems faced by the cities of developing countries such as India. Large cities in developing countries with more than 1 million in population are recording a rapid increase in population, urban area, and automobile ownership. This phenomenal growth has created intense congestion, because costs prohibit the provision of adequate transportation facilities. Gupta showed that the costs of providing roads and other transportation infrastructure increase greatly with the increase in city size (*1*).

India has an inadequate internal energy supply and depends on imported oil for its mobility. But India has few resources available to pay the bill for the oil. Environmental control regulations are practically nonexistent, so large cities face more environmental problems than cities of the developed world. Hanson found that for developing countries, the motor vehicle–dominated city is a nonsustainable urban form (*2*). He clearly demonstrated that emerging land use patterns in large cities of the developing countries have locked these cities into nonsustainable urban forms.

URBANIZATION IN INDIA

Before the 1961 census, there was no accepted definition for urban area. The 1961 census for the first time standardized the definition of an urban area (*3*). According to this definition, any urban area is a municipal corporation, a municipal area, a town/notified Area Committee, or a cantonment board. As per the definition, cities have been categorized in six groups on the basis of population, as shown in the following table:

Class	*Population*
1	More than 100,000
2	50,000 to 100,000
3	20,000 to 50,000
4	10,000 to 20,000
5	5,000 to 10,000
6	Less than 5,000

The number of Class 1 cities in various population ranges as reported in the 1971 and 1981 censuses are given in Table 1 (*4*). Table 1 also shows the classification of Class 1 cities into three categories. Cities with populations between 100,000 and 300,000 are classified as emerging cities; cities with population between 300,000 and 1,000,000 are classified as medium cities; and cities with more than 1 million population are classified as major metropolitan cities. The percentage of increase in the number of cities from 1971 to 1981 indicates that medium and emerging cities registered a greater percentage increase than the major metropolitan cities with more than 1 million population. This indicates an accentuated shift in the rural-urban migration trend.

TABLE 1 Number of Class 1 Cities by Population (*4*)

City Class	City Size	Number 1971	Number 1981	Percent Increase over 1971
Emerging Cities	100,000 - 300,000	104	147	40
Medium Cities	300,000 - 1,000,000	35	57	63
Major Metropolitan Cities	> 1,000,000	9	12	33
TOTAL		148	216	46

PLANNING EFFORTS

Over the past decades major efforts of planners for planning transportation activities in India were for such large metropolitan cities as Bombay, Calcutta, Delhi, Madras, and Bangalore. The other medium-sized and emerging cities have not received any input in terms of a systematic effort for planning the land use transportation system. During recent years, because of the serious problems in large cities, importance has been attached to these smaller urban areas to save them from chaos and environmental degradation. These cities are ideal

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for planning nonmotorized transportation, because a very high percentage of person trips and goods trips are performed through nonmotorized transportation.

Currently, the land use patterns and street configurations of the emerging cities are suitable for nonmotorized transportation. To promote nonmotorized transportation and to preserve the environment, these cities need strong transportation policies from the federal and state governments. Proper land use planning and land banking efforts may achieve nonmotorized transportation in these emerging cities. The term "land use planning" is used to focus on achieving the built environment in keeping with the nonmotorized transportation policies. To control the unplanned urban form, the planning agencies should create land banking and allow urban development only according to the land use plan. A good example of land banking was developed by the Delhi administration in formulating its land use policies for the greater metropolitan city of Delhi (*5*).

EMERGING CITIES

Chapin and Kaiser showed the area required in the United States per 100,000 people is as follows: inside city limits, approximately 6,107 acres (24.71 km^2); the total planning area is 45,171.31 acres (182.80 km^2) (*6*). Much less land area is required to support 100,000 people in India. Table 2 shows the land area requirement for various city sizes in India. Comparing the developing land area inside city limits for U.S. cities with the developed land area inside cities of India shows that approximately 60 percent less land area is needed to support 100,000 people in the emerging cities in India. It is obvious that cities in India have a large number of dwelling units per acre. Also, land devoted to streets and highways is only 12 percent as compared to 24.2 percent of developed areas for U.S. cities.

TIME AND DISTANCE

Mode of travel depends on many variables: cost and comfort, which are usually based on socioeconomic and life-cycle factors; the value that a worker places on time; and the degree to which a worker is willing to make a specified journey to work by a particular mode. Khisty showed a general transportation concept in terms of time, distance, and speed (*7*). He indicated that when the time of travel is doubled, distance covered increases tenfold as mode of travel changes, and speed of travel increases fivefold. This is because every mode is competent and efficient over a certain distance. In developing countries, affordability is a key factor in selecting a mode of travel. Thus city size, urban land area, and affordability dictate the predominant mode of travel.

Critical review of Table 2 suggests that the major percentage of trips can be performed through nonmotorized transportation up to 2.5 km. Bouladon has demonstrated that the spectrum of transportation modes can be divided into roughly five areas (*8*). When demand for transportation (vertical axis) is plotted against the speed, time, or distance measure (horizontal axis), the transportation range is well covered by the modes: walk, bike, bus, car, and aircraft.

Table 3 shows the application of the Bouladon concept to five city sizes in India. Trip length and trip time dictate the

TABLE 2 Developed Land Area and Transportation Elements for Various City Sizes in India (*9,10*)

City Size (population)	Developed Land Area (sq. kms.)	Area Under Street (sq. kms.)	Area Under Main Road (sq. kms.)	Main Road Length (kms.)	Mean trip Length (kms.)
48,000	3.84	0.46	0.23	1.15	1.0
132,000	10.56	1.27	0.63	3.15	1.5
212,000	16.96	2.04	1.02	5.10	2.5
323,000	25.84	3.10	1.55	7.15	3.5
1,070,000	85.60	10.27	5.13	20.52	5.0

TABLE 3 Theoretical Travel Mode, Speed, and Travel Time by City Size (*8*)

City Size	Mean Trip Length (kms)	Mode of Travel	Speed (km/h)	Time (min)
48,000	1.0	walk/bike	5/11.0	12/5.5
132,000	1.5	walk/bike	5/11.0	18/8.2
212,000	2.5	walk/bike	5/11.0	30/13.8
323,000	3.5	bike/bus	11.0/17.5	19/12
1,070,000	5.0	bike/bus	11.0/17.5	29.3/17.2

TABLE 4 Nonmotorized and Motorized Modal Split by City Size in India (*12*)

	NON-MOTORIZED		MOTORIZED		
City-Size	Walk	Bike	Public	Private	Hired
48,000	75	25	-	negligible	-
132,000	59	40	-	1	-
212,000	45	50	3	2	-
323,000	40	45	8	4	3
1,070,000	20	36	20	14	10

mode of travel. One can draw a line between the nonmotorized and motorized travel to a trip length of 2.5 km and travel time of 30 min walking or 13.8 min biking. Any trip in excess of 2.5 km will require some sort of motorized transportation. Thus, a suitable urban form for emerging cities around a nonmotorized transportation system for a mean trip length of 2.5 km can easily be developed.

Table 4 shows that the best estimates of a work trip modal splits in terms of nonmotorized and motorized percentage of trips for the five city sizes in India. It shows that the percentage of nonmotorized transportation trips decreases with the increased city size. In a city with a population of 48,000 or less, almost all intracity work trips are accomplished by walking or bicycling; an insignificant percentage of trips are taken by motorized transportation. For emerging cities, 85 percent of intracity trips are made by walking or bicycling, and only 15 percent are made by motorized transportation.

ENERGY AND ENVIRONMENT

Energy and the environment are critical issues in urban centers of developing countries. A series of models is developed to calculate the fuel consumption and air pollutants. FHWA provides a procedure to estimate fuel consumption and air pollution (*11*). The rates of air pollution given in the procedures are for the prevailing transportation system in the United States. In the absence of the rates for Indian conditions, these rates have been used in this study to show the amount of pollutants by city size. The models developed are

$$MWT = MTPL * LF \quad (1)$$

$$(MPT)_i = MWT * P_i * OC_i \quad (2)$$

$$G_{Ly} = 250 \sum_i (MPT)_i * (PK_L)_i \quad (3)$$

$$CO = 250 \sum_i (MPT)_i * (R_{CO})_i \quad (4)$$

$$HC = 250 \sum_i (MPT)_i * (R_{HC})_i \quad (5)$$

$$NO_x = 250 \sum (MPT)_i * (R_{NO_x})_i \quad (6)$$

where

MWT = length of motorized work trips,
$MTPL$ = mean trip length,
LF = labor force,
$(MPT)_i$ = motorized trips by mode i (km),
P_i = percentage of trips by mode i,
OC_i = vehicle occupancy for mode i,
G_{Ly} = gasoline consumption (L/year),
$(PK_L)_i$ = kilometers per liter for mode i,
CO = carbon monoxide emission (kg/year),
HC = hydrocarbon emission (kg/year),
NO_x = nitrogen oxide emission (kg/year),
$(R_{CO})_i$ = rate of CO emission for mode i (kg/1,000 veh-km),
$(R_{HC})_i$ = rate of HC emission for mode i (kg/1,000 veh-km), and
$(R_{NOx})_i$ = rate of NO_x emission for mode i (kg/1,000 veh-km).

Because of the paucity of data, many assumptions were made for automobile occupancy and fuel consumption rates for various modes as shown in Table 5. Table 6 provides an estimation of fuel consumption, and emissions of carbon monoxide, hydrocarbons, and nitrogen oxides by city size. Thus, the figures shown in Table 6 are only for comparison among city sizes. It shows that the rate of fuel consumption and air pollutants per 1,000 population increases exponentially with city size. In an emerging city with a population of 212,000,

TABLE 5 Assumed Automobile Occupancy and Fuel Consumption Rates for Various Modes in India

MODE	AUTO OCCUPANCY (person/vehicle)	FUEL CONSUMPTION RATE (km/liter)
Passenger Car	2	10
Scooter	1.4	40
Auto Rickshaw (scooter base)	2	25
Tempo (motorcycle base)	8	10
Bus	45	4

TABLE 6 Yearly Fuel Consumption and Emissions of Carbon Monoxide, Hydrocarbons, and Nitrogen Oxides by City Size in India

CITY SIZE	FUEL CONSUMPTION		CARBON MONOXIDE		HYDROCARBONS		NITROGEN OXIDES	
	Liters	L/1,000 population	kg	kg/1,000 population	kg	kg/1,000 population	kg	kg/1,000 population
48,000	negligible		-		-	-		
132,000	6,000	45.5	780	5.9	80	0.61	65	0.49
212,000	76,500	360.9	15,900	75.0	1,350	6.37	700	3.30
323,000	359,000	1111.5	87,660	271.4	7,550	23.37	3,410	10.56
1,070,000	5,485,000	5,126.2	1,722,447	1609.8	149,685	139.89	43,985	41.11

TABLE 7 Daily and Yearly Fuel Consumption Rates for Work Trips in Comparable Sizes of City in United States

City Size	Fuel Consumption (liters)	
	L/1,000 Population	L/1,000 Population
48,000	31,267	162,857
132,000	139,840	264,848
212,000	263,394	310,608
323,000	467,772	362,055
1,070,000	2,255,274	526,933

the yearly fuel consumption rate for work trips is 361 L/1,000 population. This rate is increased by three times, to 1,112 L/1,000 population, when the city size increased to 323,000 and by 14 times when the population increased to more than 1 million. The same is true for the various air pollutants. The data clearly demonstrate that the developing countries should develop a policy to control the city size to 300,000 population in order to limit the rate of fuel consumption and pollutant emissions.

The daily fuel consumption and yearly fuel consumption rates for work trips in a city of comparable size in the United States are shown in Table 7. This table is developed by considering mean trip length of work trips for various city size and the combined average fuel efficiency rates for automobiles of 6.5 km/L. A comparison between Tables 6 and 7 shows that in the United States the fuel consumption for work trips is 100 to 4,000 times higher than in cities in India. This clearly demonstrates that developing countries such as India cannot economically sustain large fuel consumption.

NONMOTORIZED TRANSPORTATION FACILITIES

Pedestrian Facilities

Even in cities with populations over 1 million, walking or walking-bicycling trips may constitute as much as 40 percent of daily work trips and 60 to 70 percent of all daily person trips (*11,13*). Improvements in pedestrian movement conserve fuel and reduce pollutants in the environment. Facilities for pedestrian movement can be achieved at a minimal capital cost as compared to facilities for vehicular traffic.

Emerging cities are ideal for the development of pedestrian facilities. These cities are growing from rural to urban form, and with the institution of comprehensive land use planning it is possible to arrange land use to keep many trip lengths short enough for walking and safe pedestrian movement. However, legal and institutional changes are needed in India to keep these facilities free from encroachments, construction debris, animals, and such.

The benefits of walking relative to other modes are numerous:

- The capital cost of vehicles is zero.
- No foreign exchange requirements are necessary.
- Infrastructure facilities requirement is minimal—only lightly surfaced paths.
- Air pollution is eliminated.

Bicycle Facilities

The bicycle is one of the most convenient and energy-efficient forms of individual transportation. Like walking, bicycling is an ideal mode of transportation in emerging cities. It helps conserve energy and preserve the environment. It provides excellent individual transportation at capital costs that are low for the user and for the government. Operating costs are also lower than they are for other modes.

A lightly surfaced path can be used as a bicycle facility and can be built at a low cost. The facility can be built exclusively for bicycles or it can include pedestrian use. In India private and government agencies provide low-interest loans to their employees for the purchase of bicycles. Governmental efforts should be expanded to enable the rest of the population to use such loans for buying bicycles.

TRANSPORTATION PLANNING IN EMERGING CITIES

Transportation planning projects undertaken in emerging cities should achieve the majority of trips by walking or walking and bicycling. This can be done in cities that are developing. By keeping the human scale in planning, a low-cost, pollution-free transportation system is achievable. Only this form of urban development is sustainable in the developing countries where most energy for mobility is imported, the foreign exchange is meager, and the balance of payment is outstanding.

A detailed study of a land use transportation system for emerging cities needs to be undertaken to demonstrate the socioeconomic development of these cities. It is also important not to overlook the necessary infrastructure requirement for the industrial development for these cities because an efficient motorized transportation system is essential for viable industrial development.

Land use transportation planning for the city of Chandigarh provides a good example for nonmotorized transportation facilities. In Chandigarh separate dedicated bike paths were planned and provided throughout the city. The intracity bike paths have minimum conflicts with automobile traffic. Conflicts are avoided or reduced through a traffic signal. The usual problems of encroachment, debris, and animals are avoided because the bike paths are designed to pass through the center of the sector in the greenbelt. The nonmotorized transportation planning efforts were possible in the very early stage of development of the capital city of Chandigarh. The emerging cities in India currently have an urban form that lends itself to conflict-free nonmotorized transportation facilities.

The federal, state, and local governments need to develop strong land use transportation policies. Land banking and zoning regulations along with strong orderly land development policies will create nonmotorized transportation in emerging cities. With the present legal and institutional constituents in India, land use planning becomes the key tool in pursuing government policies.

CONCLUSIONS AND RECOMMENDATIONS

A nonmotorized urban transportation system for emerging cities appears to be an achievable solution to many transportation problems faced by India. It has been demonstrated that as the city size increases, the rate of consumption of gasoline fuel for work trips increased exponentially. The same is true for various air pollutants. This paper clearly demonstrates that India should develop a policy to control city size to 300,000 population and develop an urban form based on human scale as the most sustainable form. The cost of providing nonmotorized transportation facilities is minimal when compared with large savings in fuel consumption and pollutants reduction.

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